WHITEPAPER

Providing freshness and quality

The important role of CO_2.

COPELAND
Engineered for Sustainability

The facts

The billions of tons of fresh food going to waste every year continues to be a leading motivation for changes in the food supply chain. Suppliers and retailers are driven to provide the best possible product with the longest possible shelf life to their customers and consumers, with as little waste as possible. While supporting value to the product's brand, supply chain efficiencies reduce waste and improve product value to consumers.

These beneficial changes in the food supply chain begin with the grower/producer in the field. Improvements in plant heredity and growing methodology, including plant nutrition, monitoring and targeted soil remediation, have provided consistent, high-quality products for consumers. To support and maintain the quality of these products, improvements in best practices for post-harvest handling, storage and transport continue to be updated and implemented.

As harvested product continues to respirate, cooling the product after harvest is the best-known way to maintain the quality of the product while extending its shelf life. The rate of respiration and aging increases close to ten (10) times for every 10°C increase in temperature above 0°C. Cooling the product slows the respiration of the perishable goods. Low respiration is further maintained when the levels of carbon dioxide (CO_2) and oxygen (O_2) are controlled in the environment. Higher concentrations of CO_2 and lower concentrations of O_2 not only slows respiration, it also makes the product less susceptible to chilling injury and the effects of ethylene, prevents the growth of molds, and makes the environment less hospitable to insects and other pests.

Perishables at different CO_2 levels

Creating and maintaining these higher levels of CO_2 and lower levels of O_2 in a low-temperature environment is particularly important for tropical and sub-tropical perishable goods. Bananas, mangos, avocados, foliage plants and similar products do not take well to cold temperatures, causing a host of issues from discoloration to very short shelf life. Modifying and controlling the atmosphere of the storage and shipping environments stabilizes the respiration of these products at the lower temperatures needed to maintain product quality and maximize product shelf life.

The ideal balance of CO_2 and O_2 in these controlled atmosphere (CA) environments varies with the type of harvest product being stored or transported. Solid products, such as fruit, absorb gasses differently for respiration than thin leafy greens. And both solid fruit and leafy green products themselves differ in gas absorption and respiration between their temperate and tropical varieties.

Example Commodity CO_2 levels

Commodity	Carrying Temperature °C	Temperature Limits °C	Freezing Temperature °C	Ventilation	Storage Life (Days)
Apricot	0	-0.5/2	-1.5	Yes	20
Grape	-0.5	-1/0.5	-1.5	Yes	50/100
Cherry	-0.5	-1/16	-1.5	Yes	20
Mango	9	7/10	-1.5	Yes	20/40
Orange	8.5	3/10	-1/-0.5	1% CO_2 max	40/50
Cabbage	0	0/1	-0.5	Yes	20
Lime	10	5/16	-1.5	1% CO_2 max	50
Iceberg	0	0/1	-0.5	Yes	40

Adapted from Sinclair (1999) and Mercantila Publishers (1989)

CO_2 in a controlled environment

These CA spaces were once the purview of only the highest-end perishable products. Advancements in films and semipermeable membranes, chemical and process gas scavengers, and environmental sensors and control systems have made CA available for more perishable product in storage and during transport. These CA systems focus primarily on maintaining a higher concentration of CO_2 and a lower concentration of O_2 in an environment without sending the product into anaerobic respiration. In normal, aerobic respiration, the harvested product consumes O_2 and produces CO_2. If there is not enough O_2, or too much CO_2, the product enters less-efficient anaerobic respiration, producing additional CO_2 and hastening product aging. This makes the monitoring and control of the CO_2 levels in a CA environment critical to the long-term freshness and shelf life of the perishable product.

CA systems start with a well-sealed, temperature-controlled storage facility or container. To initially attain the lower O_2 concentrations, after loading these spaces, the product is allowed to naturally consume the O_2, propane burners are used to consume the O_2 or nitrogen (N_2) is introduced to displace the O_2 out of the space. Similarly, the higher concentrations of CO_2 may be obtained through the natural respiration of the product or by introducing additional CO_2 into the environment. However, at the lower, more desirable storage and transport temperatures, the product respiration may be too slow to produce the desired CA environment in a reasonably short time, so CO_2 is often introduced initially and O_2 is removed. To maintain the CA environment during transport, pressure swing absorption systems (PAS) are commonly used. These systems separate gasses in the container air, while recirculating and remixing the air to maintain the desired CA balances. While some systems use special filters and membranes to separate the gases, others use beds of absorbents to pull out and hold the constituent gases. For example, CO_2 may be removed passing the air through “scrubbing” materials, such as lime, activated charcoal and water. Additionally, if one product is over-producing CO_2, excess CO_2 may be extracted and circulated into an environment needing more.

Measuring CO_2 levels

The measurement of CO_2 levels is often made using special infrared gas analyzer systems. New semiconductor technologies have improved the accuracy, repeatability and reliability of CO_2 sensing systems. Newer nondispersive infrared (NDIR) CO_2 sensors are making it possible to more cost effectively monitor the CO_2 levels in a transport container with a portable device. Recent advances in semiconducting functional materials and sensors based on carbon nanotubes (CNT) hold hope for thin and flexible mass-produced, low-cost sensors based on electrochemical responses to gasses.

Maintaining proper temperature is critical to a good, controlled atmosphere environment. Monitoring and maintaining levels of CO_2 is key to creating the best CA environment for your perishable products, maintaining the highest quality of harvested products, maximizing both freshness and shelf life, and lifting up your brand and profitability.

What is best for tracking?

So the question remains: with all these great technologies, which is the best for my real-time tracking logistics system? The answer remains: It depends upon your application. Some of the application questions to answer include:

- What are you tracking?
- How is that product transported?
- Where is that product transported?
- Are you only in cities or on popular highways?
- Are you in Europe or North America?
- How much other information about your product and shipment is needed?
- How often is an update needed?
- Do you need to communicate back to your device?
- How often and how much data is needed to be sent back?

If your trips are generally less than a day and always within a large metropolitan area, a LoRa or SigFox system may be an appropriate solution. Cellular solutions work well for travel around and between population centers. And, if your trips are more often multiple-day journeys across the outback, it may work best to step out of a LPWAN solution and use a satellite solution. When monitoring perishable products in the cold supply chain, different reporting scenarios lend themselves to different radio communications protocols. Seek technology partners with experience in your part of the cold chain to help you map out the path of your product and data. And, remember the care, detail and broad communications network watching over your next handful of fresh blueberries.

End notes

"Guide to Food Transport Fruits and Vegetables." Mercantila Publishers 1999

"Code of Practice for Handling Fresh Fruit and Vegetables in Refrigerated Shipping Containers for Australian Exports." Shipping Australia LTD. Food Science Australia. Australian Quarantine and Inspection Service. Department of Agriculture and Fisheries and Forestry.

"Transport of Temperature Sensitive Goods in Europe: Definition, Limitations, Flow Analysis and Case Studies." TFK-TransportFrsK AB. Era-Net Transport. SIR-C Swedish Intermodal Transport Research Centre.

"Fruit's Fountain of Youth: Apeel's Edible Produce Coating Could Slay Food Waste and Save Supermarkets Billions. Forbes. McGrath 2018

"Postharvest Biology and Technology of Fruits, Vegetables, and Flowers." Gopinadhan Paliyath. Dennis P. Murr. Avtar K. Handa. Susan Lurie. Wiley-Blackwell 2008